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Survey of Localization Techniques based on Mobile Beacon in Wireless Sensor Network

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Abstract: Nowadays, Wireless Sensor Networks (WSNs) are most growing research area because of its low cost, infrastructure less, increased capabilities of nodes, real-time and accurate monitoring. It is employed to gather and forward information to the destination. Location of the event or collected information is very crucial for successive operations. This information may be obtained using the global positioning system, but it is not feasible for energy constraints networks. Location of sensor nodes may be obtained through localization techniques. Localization of nodes in a sensor network is a motivating analysis space, and a lot of works are done to this point. It is highly required to design energy aware, economical and scalable localization techniques for WSNs. In this paper, we have done analyze of various localization techniques, and few possible future research directions.

Keywords: Mobile beacon, localization, wireless sensor networks, RSSI, path planning.

I. INTRODUCTION

In WSNs, sensor nodes are deployed in the real geographical environment and observe some physical parameters. WSNs have many analytical challenges. Sensors are a small device in size, low-cost accounting, and having low process capabilities. WSN's applications attracted great attention interest of researchers in recent years [1]. WSNs are different from ad hoc and mobile networks in many ways. WSNs have various applications; so, the protocols designed for ad hoc networks don't suit WSNs [2]. WSNs have a different application such as monitor environmental aspects and physical phenomena like temperature, audio and optical data, habitat monitoring, traffic control monitoring, patient healthcare monitoring, and underwater acoustic monitoring. Sensor nodes are also used in industrial, environmental, military, and civil applications [3]. WSNs have many technical limitations that affect architecture and performance of overall networks like hardware and operating system [4], medium access schemes [5], deployment [6], time synchronization [7], localization, middleware, wireless sensors and actors networks [8], transport layer, network layer, quality of service, and network security [9]. WSN's applications have opened inspiring and innovative analysis areas in telecommunication world, particularly in recent years. Localization of nodes is very crucial to find the location of nodes in sensing space [10]. Data collection without their geographical positions would be useless. Localization of nodes can be achieved by using global positioning system (GPS) but it becomes very expensive if a number of nodes are large in a given network. So far many algorithms have been come up to solve the localization issue but due to their application-specific nature, most of the solutions are not suitable for wide range of WSNs [11]. Ultra wide band based techniques are useful for the indoor environment while extra hardware would be required for the acoustic transmission-based system. These techniques have higher accuracy but expensive in terms of energy consumption and processing. Unlocalized nodes calculate their location from beacon messages broadcasts by beacon nodes, which needs much power. Incremental algorithms have been proposed to reduce this communication cost but error propagation lead inaccurate location determination [12]. To find the location of nodes is mainly based on the distance between beacon node (with known location) and unlocalized node (with unknown location). In this paper, we study sensor node localization schemes having different features used for different applications. For static and mobile sensor networks, different algorithms of localization are used. In this paper, path planning of the mobile is also considered for analysis.

The rest of the paper is organized as follows. Section II discusses background of localization techniques. Section III provides an overview of localization in WSNs. Section IV presents related work which covers both range-free and range-based localization techniques. Section V presents open issues for localization. Section VI concludes the paper.

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II. BACKGROUND OF LOCALIZATION

Localization is an crucial to determines the exact location of fixed or mobile nodes in wireless environments. Localization is motivated by military applications such as battlefield surveillance. In WSN, there are various algorithms and techniques that have been proposed for node localization. Mainly localization uses two types of nodes namely beacon node or beacon node and unknown node. Beacon node knows its own positions a priori, in contrast unknown node is not aware of its position in the network. Localization is broadly classified into two main categories: static node localization and mobile node localization. In static node localization, single or multiple nodes are used for beacon node to determine their position. In mobile node localization a mobile beacon is used to determine position of static nodes in the network.

A. Key issues

The particular requirements for localization schemes for WSNs generally depend on the nature of applications, constraints imposed by hardware and network infrastructure. Based on these, some of the specific issues concerning the design of mobility-assisted localization scheme are as follows:

- Accuracy and precision of localization: Accuracy refers to how much correct is the location estimation relative to the actual location and precision describes the consistency of the estimates [13]. Each system contains granularity of measurements that refer to the smallest measurable distance. The granularity of measurements range from few inches or bigger depending on the used equipment and technique. Similar to the previous, the required granularity of localization that is required in WSNs is also application dependent.
- Absolute versus relative locations: GPS devices in localization systems help in determining the absolute location in terms of latitude, longitude and altitude with respect to the earths coordinates [13]. On the other hand, locations may be obtained with respect to a given frame of reference, such as the location of a mobile beacon. Based on the application requirement, locations can be either absolute or relative. It is noted that a relative location can always be transformed to an absolute location if the absolute location of the reference point is known.
- Communication requirements: Communication between a sensor node and a mobile beacon or other sensor nodes can provide significant benefits such as time synchronization and improvements in accuracy and precision. However, a fundamental issue in WSNs is the minimization of communication requirements in the sensor nodes to conserve energy. This introduces unique considerations for designing the localization scheme as well.
- Cost: As cost is an important factor, so the design requirements of large scale sensor networks are: (1) to minimize the cost of sensor nodes, and (2) take the benefit of combined sensing and computational abilities of many nodes in the network [13]. Therefore, the localization system should not consists of expensive hardware. The cost involved in building external infrastructure for providing localization is also one factor but it is not that much considerable as it does not increase with network size.

B. Inherent challenges

Localization plays a significant role in many applications, few of which are briefed in introduction. However, localization itself is a complex problem to be solved because of the demanding requirements for low cost, high energy efficiency, and scalability for any network size, as well as practical issues associated with sensor node deployment. Herein, we sum up some major challenges specially faced by localization approaches to obtain accurate location information.

- Beacon trajectory: In mobility-assisted localization, unknown sensors can be localized only when they are in direct contact with the mobile beacon and receive sufficient signals from it. beacon trajectory thus has to be properly planned so as to be shortest in length as well as it should be quick and full so as to provide accurate localization. Huge localization delay along with low localization ratio and high localization error occur if the trajectory is of poor form [14]. As sensor nodes are dropped randomly, their placement pattern cannot be known beforehand. If the initial pattern is known in a dynamic environment, the final sensor node distribution may vary due to movement of wind or other factors. Therefore, the key challenge for mobility-assisted localization is the beacon trajectory that should be planned instantly instead of beforehand.
- Sensor node density: Mobility-assisted localization approaches very rarely deal with varying node densities. If the network is a dense one having enough number of mobile beacons, accurate localization result is achievable with minimum movement of mobile beacon. In contrast, for sparse networks, mobile beacon may require traversing more distance within the network area to localize sensor nodes. Therefore, for a sparse network having limited number of beacons, the main challenge for the localization problem is to obtain maximum location accuracy using optimal path movement.

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- Noisy measurements: Mobility-assisted localization approaches are required to face noisy measurements as proximity, range and angle measurements deal with noises as wireless signals are uncertain in nature. So for the success of mobility-assisted localization methods, modeling the noises and lessening the impacts on localization performance are very much necessary.
- Infrastructure-less environment: Sensors are generally deployed in some inaccessible terrain or areas where infrastructures are very less. In order to estimate the sensor nodes relative location to the moving beacon using the received signal strength, it is necessary to calibrate the system, for obtaining the propagation characteristic of the beacon in the air. Hence, the design of mobility-assisted localization schemes should be automatic without human calibration and extensive environment profiling.
- Obstacles and terrain irregularities: Obstacles and terrain irregularities jointly can also cause devastation on mobility-assisted localization process. Large rocks can occlude line of sight, prevent measuring range, or interfere with radios, introduce errors in range measurement and produce incorrect location information. In indoor environment, natural features like walls can hinder measurements as well. All these challenges are likely to come up in real life implementations, so mobility-assisted localization schemes should be able to cope up with these.
- Resource constraints: Cooperation among sensor nodes in mobility-assisted localization process is done by exchanging information between neighbouring sensor nodes. For example, as in centralized localization algorithms [15], cooperation is achieved using a central node (usually the base station/sink). Additional communication cost results due to collecting and forwarding the measurements to the base stations and sending the localization information to the nodes.

III. LOCALIZATION OVERVIEW

Localization is the process of determining the position of all sensor nodes within a wireless sensor network. The link between sensed value and the location of the source data is necessarily fundamental and important motivation for localization [16]. Localization scheme is generally categorized into two parts are: Range-based localization scheme and Range-free localization scheme.

- Range-based localization scheme is used to measure the distance or angle between beacon node and unknown node in a fixed area. The range-based scheme is further divided into two distance estimation RSSI, ToA, AoA, TDoA techniques are used. Whereas, in position estimation lateration, trilateration and multilateration techniques are used [17] [18].
- Range-free localization scheme is used to measure the distance or position between unknown nodes. Range-free localization scheme estimates the location of an unknown node without determining the distance. It has no prior knowledge about the node. For the range-free scheme, there is DV-Hop and pattern matching method is used such as fingerprinting [19] [20].

Localization is very important in many real time applications. Various techniques of range based localization are as follows:

1) Received Signal Strength Indicator (RSSI):
   RSSI is a Radio- Frequency term which is mainly used for distance measurement between transmitter and receiver. It is most popular technique for indoor and outdoor environment for improve accuracy. It is most suitable for WSN due to low cost, low power consumption, simple hardware, etc. RSSI achieves high accuracy in short distance.
2) Time of Arrival (ToA):
   It is mainly measure the distance between beacon node and target node and also proportional to the propagation time of signal. It requires high precision timing and synchronization.
3) Time Difference of Arrival (TDoA):
   The implementation of technique depends on the measurement of time of arrival (ToA). It measure the transmitters signal at a number of receiver.
4) Angle of Arrival (AoA):
   In this technique, each sensor allows evaluating the relative angles between received radio signals. It required an antenna and complex hardware.

The RSSI-based technique is more suitable estimate position due to its nature and low cost, low power consumption. Other techniques required hardware and also complex. For position estimation, multilateration technique is more required than other techniques because it performs the better result than other. Various techniques are used for position estimation are as follows:

(i) Lateration occurs when the distance between nodes is measured to calculate location.
(ii) Angulation occurs when the angle between nodes is measured to estimate location.

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(iii) Trilateration. Location of a node is calculated through distance measurement from three nodes. In this concept, an intersection of three circles is calculated, which gives a single point which is a position of a unlocalized node.
(iv) Multilateration. In this theory, more than three nodes are used in location estimation.
(v) Triangulation. In this mechanism, minimum two angles of an unlocalized node from two localized nodes are measured to calculate its position. Trigonometric laws, the law of sines and cosines are used to estimate node position [21].

Localization schemes can be further categories as beacon based or beacon free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, static or mobile sensor nodes, and range based or range free. We will briefly analyze all of these schemes.

A. *Beacon Based and Beacon Free*

In beacon-based mechanisms, the positions of few nodes are known. Unlocalized nodes get their location by these known nodes positions. Accuracy is highly depending on the number of beacon nodes. beacon-free algorithms calculate relative positions of nodes instead of computing absolute node positions [21].

B. *Centralized and Distributed*

In centralized schemes, all information is passed to one central point or node which is usually called sink node or base station. Sink node computes the position of nodes and forwards the information to respected nodes. Computation cost of the centralized based algorithm is decreased, and it takes less energy as compared with computation at an individual node. In distributed schemes, sensors calculate and estimate their positions individually and directly communicate with beacon nodes. In distributed schemes there may be clustering scheme for localization or every node can calculate its own position [22][23].

C. *GPS Based and GPS Free*

In GPS-based schemes GPS receiver has to be added to every node which makes it very costly but it gives very high localization accuracy.In GPS-free algorithms GPS is not used, and they calculate the distance between the nodes to compute relative position in the local network and it is comparatively less costly with GPS-based schemes [24] Some application required the global position of sensor nodes [21].

D. *Coarse Grained and Fine Grained*

Fine-grained localization schemes result when localization methods use features of signal strength at the receiver end, while coarse-grained localization schemes result without using received signal strength.

E. *Static and Mobile Sensor Nodes*

Localization algorithms are also designed according to the area of sensor nodes in which they are deployed. Some nodes are static in nature and are fixed at one place, and the majority applications use static nodes. It is the main reason why many localization algorithms are designed for static nodes. Few mechanisms are designed for the Few applications to use mobile sensor nodes applications [25].

IV. RELATED WORK

Recently, a large number of localization techniques and algorithms have been proposed for WSNs, and simultaneously many studies have been done to analyze existing localization techniques and algorithms. For example, in [26], Mao et al. first provide an overview of measurement techniques that can be used for WSN localization, e.g., distance related measurements, angle-of-arrival measurements and RSS profiling techniques. Then the one-hop and the multi-hop localization algorithms based on the measurement techniques are presented in detail, respectively, where the connectivity-based or range-free localization algorithms and the distance-based multi-hop localization algorithms are particularly discussed due to their prevalence in multi-hop WSN localization techniques. In addition, based on the analysis, the open research problems in the distance-based sensor network localization and the possible approaches to these problems are also discussed.

In [27], Amundson et al. present a survey on localization methods for mobile wireless sensor networks (MWSNs). First, the authors provide a brief taxonomy of MWSNs, including the three different architectures of MWSNs, the differences between MWSNs and WSNs, and the advantages of adding mobility. The MWSN localization discussed in [27] is consists of three phases: 1) coordination, 2) measurement, and 3) position estimation. In the coordination phase, sensor nodes coordinate to initiate localization, including clock synchronization and the notification that the localization process is about to begin. In the second phase, the measurement techniques, e.g., the angle-of-arrival (AOA) and the time-difference-of-arrival (TDOA) methods are presented. The measurements obtained in the second phase can be used to determine the approximate position of the mobile target node based on localization algorithms, e.g., the Dead Reckoning, the maximum likelihood estimation (MLE) and the Sequential Bayesian estimation (SBE). To the best of our knowledge, the reference [27] is the first survey focusing on MWSNs localization.

In [10], an overview of localization techniques is presented for WSNs. The major localization techniques are classified into two categories: centralized and distributed based on where the computational effort is carried out. Based on the details of localization process, the advantages and limitations of each localization technique are discussed. In addition, future research directions and challenges are highlighted. This paper points out that the further study of localization technique should be adapted to the movement of sensor nodes since node mobility can heavily affect localization accuracy of targets. However, the localization techniques proposed for mobile sensor nodes are not discussed in [10].

In [28], M.S. Aruna1 et al. have presented a detailed survey on various localization techniques and path planning mechanism for the mobile beacon node in order to reduce the collinear problem and localization error and with less path length and localization time. Various results show that proposed trajectory has less localization error when compared to the existing trajectory.

In [29], an RWP mobility model is a widely used model mostly due to its simplicity. A random destination is chosen by the mobile beacon and it travels towards the newly chosen location. In one work [30], the authors used the RWP mobility model for facilitating the localization of static nodes. The beacons positional message is transmitted by the mobile beacon at every destination. The primary disadvantage of the RWP mobility model is the non-uniform coverage of the network field. It is quite evident that while some points may be visited repeatedly by the mobile beacon while some points may never be visited by the same. It is highly difficult for determining the path length traveled by the beacon as the movement of the beacon may be stopped after a certain time interval or predefined path length.

In [31], a simple and easily implementable mobile beacon trajectory planning scheme named SCAN has been proposed. It uniformly covers the network field. The uniform coverage of the network field helps in ensuring low localization error and receiving of beacons by all the unknown sensor nodes. SCAN divides the square deployment area into sub-squares and connects their centers using straight lines.

The idea of equilateral triangle configuration idea was initially proposed in [32] for the beacon's placement to help localize the mobile sensors. Based on this idea, the LMAT algorithm is proposed in [33] where optimal beacon positions for the mobile beacon are used for obtaining better localization accuracy and coverage. In this work, it is considered that the mobile beacon moves along an equilateral triangle trajectory and transmits the beacons including the beacon position information at regular intervals.

Recently, in [34], authors proposed a path planning technique called as Z-curve. The proposed trajectory has the ability to successfully localize all the nodes with high precision and in the shortest time. Here, the basic curve of the trajectory is built based on the Z shape. The reason for choosing this shape is that such a trajectory has short jumps to overcome the collinear problem.

In [35], localization algorithms are classified into target/source localization and node self-localization. In the target localization, Single-Target/Source Localization in WSNs, Multiple-Target Localization in WSNs and Single-Target/Source Localization in Wireless Binary Sensor Networks(WBSNs) are mainly introduced. Then, in node self-localization,range-based and range-free methods are investigated. With the widespread adoption of WSNs, the localization algorithms are very different for different applications. Therefore, in the paper, the localization in some special scenarios are also surveyed, e.g., localization in non-line-of-sight (NLOS) scenarios, node selection criteria for localization in energy constrained network, cooperative node localization, scheduling sensor nodes to optimize the trade-off between localization performance and energy consumption, and localization algorithm in a heterogeneous network. Finally, the evaluation criteria for localization algorithms are introduced in WSNs.

In [36], the distance-based localization techniques are surveyed for WSNs. It is impossible to present a complete review of every published algorithm. Therefore, ten representative distance-based localization algorithms that have diverse characteristics and methods are chosen and presented in detail in [36]. The authors outline a tiered classification mechanism in which the localization techniques are classified as distributed,distributed-centralized, or centralized. Generally, centralized localization algorithms produce better location estimates than distributed and distributed-centralized algorithms. However, much more energy is consumed in the centralized algorithms due to high communication overheads for packet transmission to the base station. Distributed-centralized localization algorithms are always used in cluster-based WSNs, which can produce more accurate location estimates than distributed algorithms without significantly increasing energy consumption or sacrificing scalability.

In [37], the classification of localization algorithms is first studied based on three categories: range-based/range free, beacon based/beacon-free, distributed/centralized. Then, the localization algorithms are compared in terms of node

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density, localization accuracy, hardware cost, computation cost, communication cost, etc. Based on the analysis of existing localization algorithms, the authors try to find positions of mobile nodes in harsh environments by designing a distributed RSSI based, range-based and beacon-based localization technique.

In [38], sensor node architecture and its applications, different localization techniques, and few possible future research directions are presented. Localization techniques are classified as beacon based or beacon free, centralized or distributed, GPS based or GPS free, fine grained or coarse grained, stationary or mobile sensor nodes, and range based or range free. All the classification methods are briefly introduced, but the details of localization algorithm are not discussed. In the paper, only some traditional localization algorithms, e.g., GPS, RSSI, ToA, TDoA, AoA, Dv-hop, and APIT are compared without considering new improved algorithms. Existing localization algorithms are always classified into two major categories: range-based and range-free. However, it is difficult to classify all the localization algorithms as range-based or range-free.

Therefore, in [39], range-based and range-free schemes are further divided into two sub-categories: fully schemes and hybrid schemes. That is fully-range-based, hybrid-range-based, fully-range-free, and hybrid-range-free. It is pointed out that hybrid localization algorithms can achieve a better localization performance compared with fully localization ones. However, in hybrid localization algorithms, large computations are required to estimate locations and the time complexity of them is relatively high.

In [40], the localization algorithms in WSNs are surveyed and reclassified with a new perspective based on the mobility state of sensor nodes. A detailed analysis of the representative localization algorithms are presented according to the following four subclasses: 1) static landmarks, static nodes,2) static landmarks, mobile nodes, 3) mobile landmarks, static nodes and 4) mobile landmarks, mobile nodes. However, only beacon-based localization algorithms are studied in the paper without considering any beacon-free localization algorithms. In most localization algorithms, localization is carried out with the help of neighbor nodes. Therefore, in [41], the localization algorithms are classified as known location based localization, proximity based localization, angle based localization, range and distance-based localization. In known location based localization, sensor nodes can obtain their locations in prior either by manually configuring or using GPS. While in proximity based localization, a WSN is always divided into several clusters, and each sensor node can find out the nearness or proximity location by using Infrared (IR) or Bluetooth. All the algorithms studied in [41] are used in 2D static WSNs. They are not suitable for 3D scenarios or mobile WSNs.

In [42] Mustafa Ilhan Akbas, et al. proposed a localization algorithm for wireless networks with mobile sensor nodes and stationary actors. The proposed localization algorithm overcomes failure and high mobility of sensors node by a locality preserving approach complemented with an idea that benefits from the motion pattern of the sensors. The algorithm aims to retrieve location information at the actor nodes rather than the sensors and it adopts one-hop localization approach in order to address the limited lifetime of the WSAN. The accuracy of the proposed algorithm can be further improved with RSS or other measurement techniques at the expense of increased energy consumption. In proposed scheme [43], a subsurface current mobility model is adopted and tailored according to the requirements of the scenario. The result presented Through extensive simulations shown that the localization estimation can be realized using local multihop information. In overall, as the multi-hop chains are allowed to become longer, more positions can be estimated with the cost of lower accuracy. The selection of the maximum hop number is, therefore, an issue depending on the requirements of the network.

In [44] CamLy Nguyen et al. proposed a maximum-likelihood based multihop localization algorithm called kHopLoc for use in wireless sensor networks that is strong in both isotropic and anisotropic network deployment regions. Compared to other multihop localization algorithms, the proposed kHopLoc algorithm achieves higher accuracy in varying network configurations and connection link-models. The algorithm first runs a training phase during which a Monte Carlo simulation is utilized to produce accurate multihop connection probability density functions (described later). In its second phase, the algorithm constructs likelihood functions for each target node based on their hop counts to all reachable beacon nodes which it then maximizes to produce localization information. The main advantage of the algorithm is the use of a Monte Carlo initial training phase to generate the multihop connection probability density functions. These are then used to build likelihood functions whose maxima estimate each target node location. Since the algorithm uses full statistical information for the multihop connection probabilities, localization results are significantly more accurate for both in isotropic and anisotropic networks.

In [45] Slavisa Tomic, et al. addresses node localization problem in a cooperative 3-D wireless sensor network (WSN), for both cases of known and unknown node transmit power by investigating the target localization problem in a cooperative 3-D WSN, where all targets can communicate with any node within their communication range. In this by using RSS propagation model and simple geometry a novel objective function derived which is based on the LS criterion, which tightly approximates the ML one for small noise. The results show that the derived non-convex objective function can be transformed into a convex one by applying semidefinite programming (SDP) relaxation technique and the generalization of the proposed SDP estimator is straightforward for the case when the nodes transmit power is not known. Cooperative localization is a very difficult problem, particularly useful for large-scale WSNs with limited energy resources. the proposed scheme involves an efficient estimator based on SDP relaxation technique to estimate the locations of a number of target nodes simultaneously. The new estimator exhibited excellent performance in a variety of scenarios, as well as robustness to not knowing.

In [46] Juan Cota-Ruiz et al. have presented a routing algorithm useful in the realm of centralized range-based localization schemes which is capable of estimating the distance between two non-neighboring sensors in multi-hop wireless sensor networks. This scheme employs a global table search of sensor edges and recursive functions to find all possible paths between a source sensor and a destination sensor with the minimum number of hops. Using a distance matrix, the algorithm evaluates and averages all paths to estimate a measure of distance between both sensors. In this scheme a recursive algorithm to estimate distances between any two sensors. The algorithm finds all possible combination routes with the minimum number of hops between a sender and a target node. To find all possible routes between two sensors, the algorithm uses a data structure in each sensor that contains all neighboring sensors that are at one-hop of distance. In the searching process, each child node is expanded going forward looking for a target node. If an expanded node has no children, the searching process returns back to the parent node to continue exploring new sensors. After that, the algorithm evaluates the path distance of each found route with a weighted distance matrix. Finally, a distance estimate is computed as the mean of all path distance. The proposed algorithm is then analyzed and compared with classical and novel approaches, and the results indicate that the proposed approach outperforms the other methods in distance estimate accuracy when used in random and uniform placement of nodes for large-scale wireless networks. Moreover, due the nature of this approach to provide all multiple-trajectories between two non-neighboring nodes with the minimum number of hops, our method can be easily applied in a variety of fields, i.e., transportation, vehicle routing, web mapping, communications, geography, artificial intelligence, and/or GIS-Network analysis, to name only a few.

In [47] Shikai Shen et al. proposed an improved DV-Hop localization algorithm to ensure the accuracy of localization. this localization algorithm first employs distortion function to select the beacon nodes that can estimate average hop distance and then adopt two-dimensional hyperbolic function instead of the classic trilateration/least square method to determine the locations of unknown nodes, which are very close to their actual locations. Remarkably, the average localization error of proposed localization algorithm is lower than those of DV-Hop algorithm and its improved algorithm, under both the uniform and non-uniform node distributions and Proposed algorithm takes full consideration of the bad impact that the distant node exerts on the necessary average hop distance in positioning, and the impact that the neighboring node density of k-hop exerts on the improvement of the positioning accuracy.

In [48] Xihai Zhang et al. proposed An efficient path planning approach in mobile beacon localization for the randomly deployed wireless sensor nodes. The proposed approach can provide the deployment uniformly of virtual beacon nodes among the sensor fields and the lower computational complexity of path planning compared with a method which utilizes only mobile beacons on the basis of a random movement. The performance evaluation shows that the proposed approach can reduce the beacon movement distance and the number of virtual mobile beacon nodes by comparison with other methods. In this scheme, a path planning algorithm based on grid scan which is the entire traverse in sensor field is proposed. In order to improve the localization accuracy, the weighting function is constructed based on the distance between the nodes. Furthermore, to avoid a decrease in the localization accuracy an iterative multilateration algorithm and the start conditions of localization algorithm is also proposed. To evaluate the proposed path planning algorithm, the results of the static beacon randomly deployed and RWP mobile path in sensor field are also provided. It is obtained that proposed scheme by a mobile beacon is significantly better than localization scheme by beacon deployment randomly in localization effects.

In [49] Dexin Wang et al. discuss the benefit brought by cooperation in the context of robust localization against malicious beacons. Cooperation provides improved detection about the existence of malicious beacons, as well as the ability to estimate their true locations. This scheme investigates various loss functions and proposes an accelerated cooperative robust localization algorithm based on Huber loss function. The proposed algorithm offers accuracy comparable to existing cooperative robust localization methods but at significantly reduced computational complexity. an accelerated algorithm FARCoL was proposed based on its characteristics. Compared with CARSDP, FARCoL significantly reduces the computational complexity of the algorithm while preserving similar accuracy.

V. OPEN ISSUES

There has been extensive research on mobility-assisted sensor node localization, nevertheless, there are several important open issues especially relevant to mobility-assisted localization in a WSN which either remain unsettled or unexplored comprehensively. Some of these issues are listed below.

- Energy consumption: The problem of minimizing energy consumption of the mobility-assisted localization process deserves more attention. Even though, energy consumption issues are addressed in the existing mobility-assisted

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localization techniques, the energy efficiency goal still remains challenging.

- Design complexity The moving trace of mobile beacon must be optimized since mobile beacons are only capable of low-speed and short-distance mobility in the real environment due to high power consumption of locomotion. Since the distribution of mobile beacons can affect location performance in static WSNs, therefore, efficient trajectory planning for mobile beacons can further increase location accuracy for target estimation.
- Non-convex topologies: Localizing the sensor nodes located in the boundary is a problem because less information is available about them and that too of lower quality. This problem is exacerbated when a node deployment area has a non-convex shape. Sensor nodes outside the main convex body of the deployment area can often prove to be unlocalizable. Even when locations are found, the results tend to feature disproportionate error. Further, an efficient trajectory planning for mobile beacons can increase location accuracy in such situation.
- Cost: Several existing works show that using mobile beacons for localization of sensor node is beneficial, as extra measurements on spatial relationships are provided along their corresponding trajectories. But, a mobile beacon, having more resources compared to an ordinary sensor node, is expensive. So, for localization, only a small number of mobile beacons can be actually used. Also, small numbers of mobile beacons must effectively cooperate with sensor nodes to obtain maximum utility.
- Three-dimension localization: In the existing scenario, sensor node localization is typically used for finding out the location of nodes in a two-dimensional network area. However, in real life application, sensor nodes are usually deployed in a three-dimensional space, which leads to differences in both ranging results and localization schemes. Investigation on mobility-assisted localization schemes focusing on three-dimensional space is of particular interests to real life applications of WSNs. In [50], an attempt is made to localize the sensor nodes in a three-dimensional network. However, the existing localization schemes in three-dimensional space are not completely examined.

VI. CONCLUSION

In this paper, we presented a survey and taxonomy on localization for mobile wireless sensor networks. Localization in MWSNs entails new challenges that result from integrating resource-constrained wireless sensors on a mobile platform. The localization methods and algorithms that provide greater accuracy on larger-footprint mobile entities with fewer resource restrictions are no longer applicable. Similarly, centralized and high-latency localization techniques for static WSNs are undesirable for the majority of MWSN applications. There are several directions for future work in MWSN localization. Currently, a tradeoff exists between the rapid execution of an algorithm and its accuracy. Additional work is needed that focused on reducing run-time latency while maintaining positioning accuracy. In addition, the majority of localization algorithms to date are centralized. For mobile sensor localization, this is often a poor design choice, due to the additional latency and energy costs incurred. The development of more distributed localization techniques would be a welcome addition to MWSN localization.

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